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HOW TO FIND THE TIME AT SEA IN LESS THAN A MINUTE;

BEING

NEW AND ACCURATE METHODS,

WITH SPECIALLY ADAPTED

TABLES.

BY

A. C. JOHNSON, R.N.

AUTHOR OF

"On finding the Latitude and Longitude in Cloudy Weather," &c.

SIXTH EDITION.

London:

PUBLISHED BY J. D. POTTER,

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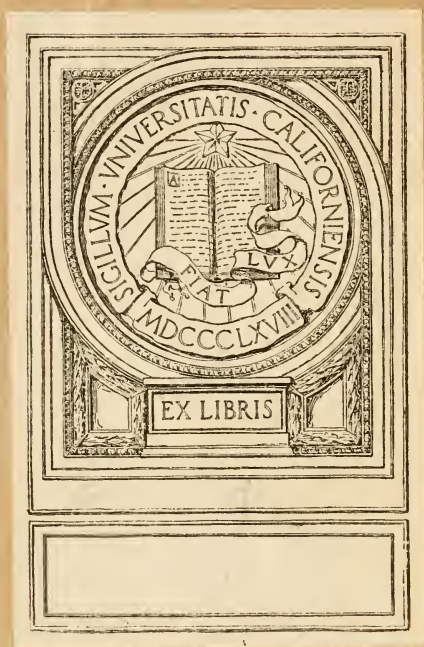
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1918.

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PREFACE TO THE FIFTH EDITION.

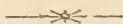


THE Tables (A) (B) (C) as given in this edition, are intended for general use and although contracted so that all the logs requisite for working a "Chronometer" are displayed at one view, the time may be found by them within a second or two of that obtained by the ordinary rules. The special Table (D) may be used when the sky is clear, and the observation can be taken in the manner indicated; the advantage of this being that *only a single logarithm has to be looked out after the observation has been taken*, so that finding the time is reduced to the most simple and expeditious process in the whole range of nautical astronomy (*vide* p. 8), while in point of accuracy it is not inferior to the former method.

The very favourable notice accorded to these little tables by Lieut. English, R.N., in his highly scientific and valuable articles on Navigation which have from time to time appeared in the "Field" newspaper, and the marked approval which they have met with from numerous officers of our own and foreign services, as well as from the mercantile marine, have encouraged the author to introduce into this edition sundry alterations and improvements which he hopes will still further add to the usefulness of the book.

DARTMOUTH, 1907.

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INTRODUCTION.



THE practice of working out the sights for longitude with the D.R. latitude, and of subsequently correcting the resulting longitude for the error in this latitude, is, in the present day, generally followed. Now it will make no difference in the ultimate result if, instead of the D.R. latitude an *assumed* latitude approximating to it be used—the object being to reduce the meridian zenith distance (*which is the sum or difference of the latitude and declination, according as they are of opposite or like names*) to an exact number of degrees, so that it may correspond with the M.Z.D. in Table (D). For a like reason the altitude is taken to an exact degree, a matter of perfect simplicity to a practised observer, and, when taken, no further correction is necessary. Should, however, the weather be cloudy, and the altitude be taken in the usual way, we can easily correct the log. from Table (D) for the minutes of altitude, as shown on p. 12.

The observation is supposed to be taken under the usual conditions as to the bearing from the meridian, and to an exact degree by allowing the correction in altitude the opposite way. Thus for 20 ft. and 30° , the correction in altitude for the sun is $+10'$; and if the index error be $+1'$, the combined correction is $+11'$. If, therefore, the sextant be set at $29^{\circ} 49'$, the *true* altitude of the Sun's centre will be 30° at the moment the lower limb is in contact with the horizon.

For a star the correction in altitude must be added instead of subtracted, but the index error must be applied as before. Thus, for 20 ft. and 30° , the correction in altitude is $-6'$, and if the index error be $+1'$ the combined correction will be $-5'$; if, therefore, the index be set at $30^{\circ} 5'$, the true altitude will be 30° when the star is in contact with the horizon. The longitude deduced from the time thus found is to be corrected for the error in the *assumed* latitude in the usual way. (*Vide* p. 12.)

TO FIND THE TIME BY TABLE (D).

I.—Assume a latitude that will make the M.Z.D. an *exact* number of degrees,* and let this be called Lat. A.

II.—For this M.Z.D., and the altitude take out the logarithm from Table (D). This added to the log. secants of the assumed latitude and declination, will be the log. versine of the hour angle, which will be found in the part of Table (B) indicated by the *approximate time, or hour angle*.

If the body be East of Meridian, subtract the H.A. found as above from 24 hours.

The longitude deduced from this time is to be corrected for the error in the *assumed* latitude by Table (E).

EXAMPLES.

I.—Lat. D.R. $30^{\circ} 25' N.$ Dec. $19^{\circ} 45' S.$ Alt. 28° .

Lat. A. $30^{\circ} 15' N.$ log sec. 636

Dec. $19^{\circ} 45' S.$ „ „ 263

M.Z.D.	50	0	} log. tab. (D)	2388
Alt.	28	0		

H.A. 2h. 32m. 27s. log vers. 3287

II.—Lat. D.R. $52^{\circ} 30' N.$ Dec. $1^{\circ} 30' N.$ Alt. 19° .

Lat. A. $52^{\circ} 30' N.$ log sec. 2156

Dec. $1^{\circ} 30' N.$ „ „ 4

M.Z.D.	51	0	} log. tab. (D)	4825
Alt.	19	0		

H.A. 3h. 59m. 44s. log vers. 6982

The assumed latitude need not differ from the D.R. latitude by more than $30'$, and will not, therefore, affect the accuracy of the result.

On the next page is shown the practical application of the above in finding the longitude at noon, and the longitude corresponding to the D.R. latitude.

* To do this make the minutes of latitude equal to the minutes of declination, when they are of the *same* name, and when they are of contrary names subtract the minutes in the declination from $60'$ to obtain the minutes of assumed latitude.

III.—At 8.30 A.M., in lat. D.R. $40^{\circ} 35' N.$, G.A.T. by chronometer 22h. 20m. 20s., true alt. $\odot 30^{\circ}$, run to noon N.N.W. $30'$, lat. by mer. alt. at noon $40^{\circ} 52' N.$ Required the true longitude at noon.

Lat. A.	$40^{\circ} 30' N.$	1190	Az. by TABLES.*
Dec.	$3^{\circ} 30' N.$	8	
M.Z.D.	$37^{\circ} 0'$	4751	Lat. $40^{\circ} N.$
Alt.	$30^{\circ} 0'$		H.A. 3.30 } = S. $66^{\circ} E.$
H.A.	3h. 30m. 40s.	5949	
S.A.T.	20 29 20		
G.A.T.	22 20 20		
	1 51 0		
= $27^{\circ} 45' W.$, at 8.30 A.M. (long. A)			

How to find the longitude simultaneously with the latitude at NOON.

Lat. A.	$40^{\circ} 30' N.$	Long. A.	$27^{\circ} 45' W.$
Run	$28 N.$	Run	$15 W.$
Approx. lat.	$40^{\circ} 58' N.$	Approx. long.	$28^{\circ} 0' W.$
Lat. mer. }	$40^{\circ} 52' N.$	Cor. $.53 \times 6$	$3\frac{1}{2} W.$
Alt. }			
Corr.	$6 S.$	True long.	$23^{\circ} 3\frac{1}{2}' W.$

If it were required to find the longitude corresponding to the D.R. latitude at 8.30 A.M., we should have:—

Lat. A.	$40^{\circ} 30' N.$	Long. A.	$27^{\circ} 45' W.$
D.R.	$40^{\circ} 35' N.$	Corr. $.58 \times 5$	$3 E.$
Corr.	$5 N.$	Approx. long. at 8.30	} $27^{\circ} 42' W.$

The correction for longitude, $.58'$, is taken from Table (E).

To name the correction for the longitude, *vide* page 12.

The bearing found by Azimuth Table, when exceeding 90° , must be subtracted from 180° , and reckoned from the opposite point—thus, N. $120^{\circ} W.$ would be S. $60^{\circ} W.$, &c.

* Those given in "Cloudy Weather" may be used for this purpose.

To find the position AT NOON by the Chart.

Through the point given by the *approximate* latitude and longitude at noon, draw the position line, or (in this case) the line at right angles to S. 66° E. Then where this is cut by the parallel of the *true* latitude will be the true place of the ship.

To explain how in actual practice the Time may be found IN A FEW SECONDS.

As the declination, and therefore the assumed latitude which depends on it, are known before the observation is taken, we are already provided with the M.Z.D., and the two log secants; a *single* logarithm only will then be required to complete the process. Thus, in Ex. I., p. 6, the declination being 19° 45' S., and the ship between 30° N. and 31° N., it is evident that the assumed latitude must be 30° 15' N., therefore we have—

Lat. A.	30° 15' N.	636
Dec.	19 45 S.	269
M.Z.D.	50 0	899 N.

Having subsequently observed the altitude to be 28° we have—

	N.	899		
Log. tab. (D)	2888			
			h.	m.
Log. vers.	3287	=	2	32 27

The time is thus found in a *few seconds* and with sufficient accuracy for all practical purposes at sea.

Application of the above Principle to finding the Position by TWO OBSERVATIONS.

Let us suppose that the foregoing observation has been taken; that the longitude deduced from it is 20° 45' W., and that the ship has run E.S.E. 22' till 4.30 P.M., we have—

Lat. A.	30° 15' N.	Long. A.	20° 45' W.
Run	8 S.	Run	23 E.
Lat. B.	30 7 N.	Long. B.	20 22 W.

The declination being now $19^{\circ} 47'$ S., suppose, and the ship being between lat. 30° and 31° N., we assume $30^{\circ} 13'$ N. for lat. C. Hence we have:—

Lat. C.	$30^{\circ} 13' \text{ N.}$	635
Dec.	$19 \ 47 \ \text{S.}$	264
	<hr/>	<hr/>
M.Z.D.	50 0	899 (N.)
	<hr/>	<hr/>

The second altitude is now taken, and is found to be 8° , therefore, as before:—

N.	899				
Log. tab. (D)	7021		h.	m.	s.
	<hr/>				
	7920	=	4	30	32
	<hr/>				

Now, supposing that the longitude resulting from this time is $20^{\circ} 52' \text{ W.}$ (or long. C), we have then:—

	Lats.		Longs.		Az.		Position Lines.
B	$30^{\circ} \ 7' \ \text{N.}$	B	$20^{\circ} 22' \ \text{W.}$	S.	$41^{\circ} \ \text{W.}$	N.	$49^{\circ} \ \text{W.}$
C	$30 \ 13 \ \text{N.}$	C	$20 \ 52 \ \text{W.}$	S.	$61 \ \text{W.}$	N.	$29 \ \text{W.}$

Laying down B and C on the chart, and drawing the corresponding position lines, the point in which they intersect will be the true place of the ship at the time of the *second* observation.

The above principle is equally applicable to two stars, taken in the morning or evening twilight, either simultaneously or in quick succession; and, as it involves only about a quarter of the work of an ordinary ‘*Sumner*,’ and will give just as good results, it is strongly commended to the notice of the practical navigator.

Obs.—The difference of bearing should not be less than $1\frac{1}{2}$ or 2 points; and, as a general rule, should exceed the less bearing. This applies to all heavenly bodies.

To find the Time **SIMULTANEOUSLY** with the Altitude.

As shown on page 8, we can determine beforehand the M.Z.D. and N.; we can therefore take out the H.A. for a few consecutive degrees, which will include the altitude at the time we wish to take the observation.

Thus, for M.Z.D. 50° , N. 899, and altitudes 29° , 30° , 31° , we have :

899	899	899
1986	1547	1064
<hr/>	<hr/>	<hr/>
2885	2446	1968
<hr/>	<hr/>	<hr/>

(a) 2h. 25m. 18s. (b) 2h. 17m. 53s. (c) 2h. 10m. 14s.

If, therefore, the true altitude is found to be either of the above degrees, the corresponding H.A. is known *without further calculation*.

The altitudes to be selected will, of course, depend on the time at which it is intended to take the observation. Suppose, for instance, we fix upon 8 A.M., and that the M.Z.D. is 50° , and N. 899, as before. Subtracting N. from the log vers. H.A., we look for the remaining log under the M.Z.D. 50° , in Table (D), when in a line with it we find the altitude thus :—

$$\begin{array}{rcl}
 \text{Log. vers. } 4h. & = & 6990 \quad \text{Tab. (C).} \\
 \text{N.} & = & \underline{899} \\
 \text{Log. alt.} & = & \underline{6091}
 \end{array}$$

Now, in the column M.Z.D. 50° , we find that 6091 comes between the logs. of 13° and 14° . Hence we may select 13° , 14° , and 15° , for which we take out the time, as above.

So that, if required, while one person is taking the altitude, a second may be finding the time from the Tables.

If, owing to clouds, the altitude cannot be observed as explained, the log. from Table (D) may easily be corrected for the minutes of altitude, as shown on p. 12.

From the above hour-angles and altitudes may be found the Bearings, by the Azimuth Tables, and thence the Variation, &c., if required.

ON FINDING THE TIME BY TABLES (A), (B), (C).

(These Tables are to be used when the observation is taken in the usual way, and as they are all on the same opening, a great saving of time and trouble is thereby effected.)

From Table (A) are taken the nat. versines of the Z.D. and M.Z.D., and the H.A. corresponding to their difference.

The log. versine of this H.A., Table (C), added to the log. secants of latitude and declination, Table (B), will be the log. versine of the H.A., to be taken from the part of Table (C), indicated by the *approximate* time.

EXAMPLES.

I.—At about 4h. 40m. P.M., in lat. $10^{\circ} 35' N.$, \odot Z.D. was $76^{\circ} 32'$, and declination $23^{\circ} 23' S.$

Tab. A.					Lat.	$10^{\circ} 35' N.$	74 sec.
					Dec.	$23^{\circ} 23' S.$	372 „
N. Vers.	1706	...	...	...	M.Z.	33	58
„	7672	...	...	...	Z.D.	76	32
Diff.	5966†	...	...	...	4h. 24m.	49s.	7756 log vers.
					H.A.	4	40 46 8202 „

II.—At about 4h. 10m. P.M., in lat. $10^{\circ} 5' N.$, \odot Z.D. was $63^{\circ} 35'$, and declination $23^{\circ} 19' N.$

Tab. A.					Lat.	$10^{\circ} 5' N.$	67* sec.
					Dec.	$23^{\circ} 19' N.$	370* „
N. Vers.	266*	...	...	...	M.Z.	13	14
„	5551	...	...	...	Z.D.	63	35
Diff.	5285	...	...	...	4h. 7m.	28s.	7230 log. vers.
					H.A.	4	21 48 7667 „

When the sun is west of mer. the H.A. is *apparent time*. When east, subtract the H.A. from 24 hours.

When the sum of the logs. exceeds four figures, reject the fifth figure on the left.

The parts marked with an asterisk may be written down before the observation is taken, thus enabling the remaining part of the calculation to be quickly gone through.

In using Table (C) it may sometimes be required to subtract an apparently greater logarithm from one apparently less, in which case the latter must be increased by 10,000, which is done by prefixing 1.

Thus : $0026 - 9970 = 10026 - 9970 = 0056$.

† Here diff. 5966 gives 4h. 24m. 49s. by Table (A). And 4h. 24m. 49s. give log. vers. 7756 by Table (C). In Ex. II. 5285 gives 4h. 7m. 28s. by Table (A), and 4h. 7m. 28s. give log. vers. 7230 by Table (C).

TO FIND THE TIME BY A STAR.

Find the hour-angle as in either of the preceding examples; then to the star's H.A. add its R.A., and from the sum (increased, if necessary, by 24h.) subtract the R.A. of the mean Sun. The remainder will be mean time at ship. The longitude is then found in the usual way.

N.B.--If the star is East of meridian, subtract the H.A. found as above from 24 hours.

The star's bearing, when required, may be taken from Burdwood's Tables, or from "The Bearings of the Principal Bright Stars," by the Author, published by J. D. Potter, London, price 3s.

To take out the Log. from Table (D) when there are minutes in the Altitude.

Take the difference of the logs. for the two degrees of altitude between which the given altitude lies, multiply it by the minutes expressed as the decimal of a degree*, and subtract.

Thus for M.Z.D. 10° and Alt. $20^{\circ} 24'$

We have for Alt. 20° 8081

Diff. $112 \times .4 =$ 45

Log. required 8036

Again, for M.Z.D. 4° , and Alt. $25^{\circ} 20'$

We have 7596

Diff. $120 \times .33 =$ 40

Log. required 7556

As the logs. decrease, they are conveniently arranged for subtracting.

To correct the longitude for an error in the latitude.

Table (E) gives the correction for 1' error in the latitude—this, multiplied by the latitude correction, will be the correction required.

To name the Correction.

Under the sun's bearing, at the time of observation, write the opposite bearing, and connect the letters diagonally,

Thus for Bearing N.W.

×

We have S.E.

* The multiplier may be taken from Table (D), p 25.

Which shows that a North correction of latitude gives an East correction of longitude, and *vice versa*.

Ex. lat 30° N. \odot Bearing N. 80° E., corr. of lat. $20'$ S.

$$\begin{array}{rcl} \text{Lat. } 30^{\circ} & & \text{N.E.} \\ \text{Az. } 80^{\circ} & = & 0^{\circ} 20' \\ & & \text{S.W.} \end{array}$$

\therefore The correction = $'20 \times 20$ or $4'$ E.

The name of the correction may also be found by reversing the first letter of the bearing, thus for N.E. we have S.E., showing that a corr. S. gives E. and *vice versa*.

EXAMPLES FOR PRACTICE.

Finding the Hour-Angle by Table (D).

(1.)	Lat. assumed, $50^{\circ} 30'$ N.	Dec. $1^{\circ} 30'$ N.	Alt. 24°	H.A. about $3\frac{1}{2}$ hrs.
(2.)	" $40^{\circ} 45'$ S.	" $10^{\circ} 15'$ N.	" 15°	" 4 "
(3.)	" $7^{\circ} 15'$ N.	" $2^{\circ} 15'$ N.	" 50°	" $2\frac{1}{2}$ "
(4.)	" $30^{\circ} 40'$ N.	" $1^{\circ} 20'$ S.	" 11°	" $2\frac{1}{4}$ "
(5.)	" $29^{\circ} 10'$ N.	" $12^{\circ} 10'$ N.	" 33°	" 4 "

ANSWERS.

- (1.) 3h. 30m. 16s. (2.) 3h. 59m. 12s. (3.) 2h. 31m. 3s. (4.) 2h. 19m. 1s.
(5.) 3h. 55m. 37s.

Finding the Hour-Angle by Tables (A), (B), (C).

(1.)	True Lat. $50^{\circ} 21'$ N.	Dec. $12^{\circ} 10'$ N.	Alt. $40^{\circ} 30'$	H.A. about $2\frac{1}{2}$ hrs.
(2.)	" $40^{\circ} 30'$ S.	" $10^{\circ} 51'$ N.	" $35^{\circ} 17'$	" $1\frac{1}{2}$ "
(3.)	" $20^{\circ} 10'$ N.	" $10^{\circ} 20'$ N.	" $50^{\circ} 15'$	" $2\frac{3}{4}$ "
(4.)	" $2^{\circ} 5'$ S.	" $1^{\circ} 3'$ S.	" $60^{\circ} 10'$	" 2 "

ANSWERS.

- (1.) 2h. 34m. 33s. (2.) 1h. 21 m. 30s. (3.) 2h. 40m. 13s. (4.) 1h. 59m. 17s.

The M.Z.D. and N., having been previously determined; to find the Hour-Angle.

(1.)	M.Z.D. 50°	N. 295	Alt. 20°	H.A. about 3 hours.
(2.)	" 43	N. 1216	" 17	" " 4½ "
(3.)	" 45	N. 3126	" 15	" " 6½ "

ANSWERS.

(1.) 3h. 9m. 12s.	(2.) 4h. 20m. 54s.	(3.) 5h. 41m. 52s.
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Correcting Log. Table D, for Minutes.

(1.)	M.Z.D. 10°	Alt. 40° 20'
(2.)	" 20	" 13 29
(3.)	" 30	" 20 46

ANSWERS.

(1.) 5284.	(2.) 5889.	(3.) 7083.
------------	------------	------------

Correcting the Longitude, for an Error in Latitude.

(1.)	Lat. 50° N.	Bearing S. 60° E.	Corr. for Lat. 20' N.
(2.)	" 40 S.	" S. 70° W.	" 10 S.
(3.)	" 20 N.	" N. 75° E.	" 15 N.

ANSWERS—CORRECTIONS.

(1.) 19' E.	(2.) 5' E.	(3.) 4' W.
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EXPLANATION OF THE TABLES.

*When a logarithm has to be taken out in two parts, place the forefinger of the left-hand on one part and the pen on the other, when the two parts are easily added together at sight.**

* The parts for the minutes seldom exceed two figures, and frequently only a single figure is required to be added.

Tab. (A). *To take out Nat. Vers.* $31^{\circ} 53'$: We have 30° at the side, and $1^{\circ} 45'$ at the top, or $31^{\circ} 45' = 1496$, and the parts for $8'$ (to make up $53'$) are 12—which, being added, we have 1508; the Nat. Vers. required.

To take out Nat. Vers. $59^{\circ} 25\frac{1}{2}'$: We have 55° at the side, and $4^{\circ} 15'$ at the top, or $59^{\circ} 15' = 4887$, and the parts $10\frac{1}{2}'$ (to make up $25\frac{1}{2}'$) are 26—which, being added, we have 4913.

This Table is arranged in two parts. The second being supposed to be a continuation of the first from left to right,* so that any versine not appearing in the first part will be found in the second, and *vice versa*.

To take out the time for Nat. Vers. 4188: The Nat. Vers. next less is 4157, which gives 3h. 37m., and the diff., 31, gives 54 seconds: hence the time is 3h. 37m. 54s.

Conversely: The Nat. Vers. of 3h. 37m. 54s. is 4188, for 3h. 37m. gives 4157, and 54s. give 31—which, being added, we have 4118 as above.

Tables (B) and (C) are used in the same manner.

The use of Table (D) when there are minutes in the altitude is explained on p. 12.

To convert Arc into Time by Table (A).

Ex.—*Convert* $76^{\circ} 40'$ *into time*: We have $76^{\circ} 30' = 5$ h. 6m., and $10' = 40$ s.
 $\therefore 76^{\circ} 40' = 5$ h. 6m. 40s.

Conversely: 5h. 6m. $40'' = 76^{\circ} 40'$, for 5h. 6m. $= 76^{\circ} 30'$, and 40s. $= 10'$
 $\therefore 5$ h. 6m. 40s. $= 76^{\circ} 40'$.

For an Arc greater than 90° subtract 90° ; convert the remaining degrees into time and add 6h., and for time exceeding 6h., subtract 6 hrs., convert the remaining time into Arc and add 90° .

To find the Natural Versine of an Arc greater than 90° . Subtract the Nat. Vers. of its supplement from 19999.

Thus for $120^{\circ} 30'$ (whose supplement is $58^{\circ} 30'$) we have Nat. Vers. $59^{\circ} 30' = 4925$.

$\therefore 19999 - 4925 = 15074 = \text{Nat. Vers. } 120^{\circ} 30'$

Conversely: Nat. Vers. $15074 = 120^{\circ} 30'$.

For $19999 - 15074 = 4925 = 59^{\circ} 30'$.

And $180^{\circ} - 59^{\circ} 30' = 120^{\circ} 30'$.

* In the same way as Table B.

To convert a Nat. Vers. into a Log. Vers. :

E. —Convert Nat. Vers. 7168 into a Log. Versine.

By Table (A), Nat. Vers. 7168 = 4h. 54m. 12s. = Log. Vers. 8554, Table (C).*

III. To find the Hour-Angle of a Star, referred to the Meridian below the Pole.

To obtain the M.Z.D. in this case add together latitude and declination and subtract the sum from 180°, then proceed as before.

EXAMPLE.

Lat. 50° 20' N. Dec. 48° 30' N. Z.D. 79° 40' .

M.Z.D. 81° 10' 8465 Lat. 50° 20' 1950

*Z.D. 79 40 8207 Dec. 48 30 1787

Nat. Vers. 258 = Log. Vers. 4114

H.A. 1h. 20m. 28s. 7851

If the M.Z.D. exceeds 90°, find its Nat. Vers. as above.

As in this particular case the M.Z.D. will always be greater than the Z.D., it is written down first.

TABLES FOR CORRECTING THE OBSERVED ALTITUDE.

(.) CORR. FOR SUN'S OBS. ALT. +													CORR. FOR STAR'S OBS. ALT. -												
HEIGHT IN FEET.													HEIGHT IN FEET.												
ALT.	5	10	15	20	25	30	35	40	45	50	55	60	ALT.	5	10	15	20	25	30	35	40	45	50	55	60
6	5	5	4	4	3	3	2	2	1	1	0	0	6	10	11	12	13	13	14	14	15	15	16	16	16
7	7	6	5	4	4	3	3	3	2	2	1	1	7	9	10	11	12	12	13	13	14	14	15	15	15
8	7	6	6	5	5	4	4	3	3	3	3	2	8	9	10	10	11	11	12	12	13	13	14	14	14
10	9	8	7	6	6	5	5	5	4	4	4	4	10	7	8	9	10	10	11	11	11	12	12	12	13
15	10	9	9	8	8	7	7	6	6	6	5	5	15	6	7	7	8	8	9	9	10	10	11	11	11
20	11	10	10	9	9	8	8	7	7	7	6	6	20	5	5	6	7	7	8	8	9	9	10	10	10
25	12	11	10	10	9	9	8	8	7	7	6	6	25	4	5	6	6	7	7	8	8	9	9	10	10
30	12	11	11	10	10	9	9	8	8	8	7	7	30	4	5	5	6	6	7	7	8	8	9	9	9
35	13	12	11	10	10	9	9	9	8	8	7	7	35	3	4	5	6	6	7	7	8	8	9	9	9
40	13	12	11	11	10	10	9	8	8	8	7	7	40	3	4	5	5	6	6	7	7	8	8	8	9
45	13	12	11	11	10	10	10	9	9	9	8	8	45	3	4	5	5	6	6	7	7	8	8	8	8
50	13	12	11	11	10	10	10	9	9	9	9	8	50	3	4	5	5	6	6	7	7	8	8	8	8
60	13	12	12	11	10	10	10	9	9	9	8	8	60	3	4	4	5	5	6	6	7	7	8	8	8
70	13	13	12	11	11	10	10	9	9	9	8	8	70	2	3	4	5	5	6	6	6	7	7	8	8
80	14	13	12	11	11	10	10	10	9	9	8	8	80	2	3	4	4	5	5	6	6	7	7	7	8

When there are fewer than four figures in the Nat. Vers. make them up to four by adding ciphers : thus, in following example, Nat. vers. 258 becomes 2580 = 2h. 48m. 20s.
Tab. (A), = Log. Vers. 4114 Tab. (C).

TABLES.

18
TABLES FOR FINDING

Table (A) NAT.-VERSINES of M.Z.D. and Z.D.											PARTS.													
Time.	Arc.	m	m	m	m	m	m	m	m	m	s s s s	s s s s	s s s s	s s s s	s s s s	s s s s	s s s s	s s s s	s s s s	s s s s	s s s s	s s s s	s s s s	s s s s
h. m.	°	0	0	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0 0	0	0	0	0	0	0	2	3	5	6	8	1	1	1	1	1	1	1	1	1	1	1	1	1
20	5	38	42	46	50	55	59	64	69	75	80	1	1	1	2	2	2	2	3	3	3	4	4	4
40	10	152	160	167	175	184	192	201	210	219	228	1	1	1	2	2	3	3	4	4	5	6	7	8
1 0	15	341	352	364	376	387	399	412	424	437	450	2	1	2	2	3	4	5	6	6	7	8	9	10
20	20	603	618	633	649	664	680	696	712	728	745	3	1	2	3	4	5	6	7	8	9	11	12	13
40	25	987	956	974	993	1012	1031	1051	1070	1090	1110	3	1	3	4	5	6	8	9	10	12	13	14	15
2 0	30	1340	1362	1384	1406	1428	1451	1474	1496	1520	1543	4	2	3	5	6	8	9	11	12	14	15	17	18
20	35	1808	1834	1859	1884	1910	1936	1961	1987	2014	2040	4	2	3	5	7	9	10	12	14	15	17	19	21
40	40	2340	2368	2396	2424	2453	2482	2510	2539	2569	2598	5	2	4	6	8	10	12	13	15	17	19	21	23
3 0	45	2929	2960	2991	3022	3053	3085	3116	3148	3180	3212	5	2	4	6	8	10	13	15	17	19	21	23	25
20	50	3572	3606	3639	3673	3707	3741	3775	3809	3843	3878	6	2	5	7	9	11	14	16	18	20	23	25	27
40	55	4264	4300	4336	4372	4408	4444	4481	4517	4554	4590	6	2	5	7	10	12	15	17	19	22	24	26	29
4 0	60	5000	5038	5076	5114	5152	5190	5228	5267	5305	5344	6	3	5	8	10	13	15	18	20	23	26	28	31
20	65	5774	5813	5853	5893	5933	5973	6013	6053	6093	6133	7	3	5	8	11	13	16	19	21	24	27	29	32
40	70	6580	6621	6662	6703	6744	6786	6827	6868	6910	6951	7	3	6	8	11	14	17	19	22	25	28	30	33
5 0	75	7412	7454	7496	7538	7581	7623	7666	7708	7750	7793	7	3	6	8	11	14	17	20	23	25	28	31	34
20	80	8264	8306	8350	8393	8436	8479	8522	8565	8608	8651	7	3	6	9	11	14	17	20	23	26	29	32	34
40	85	9128	9172	9215	9259	9302	9346	9390	9433	9477	9520	7	3	6	9	12	15	17	20	23	26	29	32	35

Time.	Arc.	m	m	m	m	m	m	m	m	m	s s s s	s s s s	s s s s	s s s s	s s s s	s s s s	s s s s	s s s s	s s s s	s s s s	s s s s	s s s s	s s s s	s s s s
h. m.	°	2	3	0	3	15	3	30	3	45	4	0	4	15	4	30	4	45	4	1	2	3	4	5
0 10	0	10	12	14	16	19	21	24	27	31	34	1	1	1	1	1	1	1	1	1	1	1	1	1
30	5	86	91	97	103	110	116	123	130	137	144	1	1	1	1	2	2	3	3	4	4	5	5	6
50	10	237	247	256	266	276	287	297	308	319	330	2	1	2	2	3	3	4	5	5	6	7	8	9
1 10	15	463	476	489	503	517	531	545	559	574	588	2	1	2	3	4	5	6	7	8	9	10	11	12
30	20	761	778	795	812	829	847	865	882	900	919	3	1	2	3	5	6	7	8	9	11	12	13	14
50	25	1130	1150	1171	1191	1212	1233	1254	1275	1296	1318	3	1	3	4	6	7	8	10	11	13	14	15	16
2 10	30	1566	1590	1613	1637	1661	1685	1710	1734	1759	1784	4	2	3	5	6	8	10	11	13	15	16	18	19
30	35	2066	2093	2120	2147	2174	2201	2229	2256	2284	2312	5	2	4	5	7	9	11	15	16	18	20	22	24
50	40	2627	2657	2686	2716	2746	2776	2807	2837	2867	2898	5	2	4	6	8	10	12	14	16	18	20	22	24
3 10	45	3244	3276	3309	3341	3374	3407	3439	3472	3506	3539	5	2	4	7	9	11	13	15	17	20	22	24	26
30	50	3912	3947	3982	4017	4052	4087	4122	4157	4193	4229	6	2	5	7	9	12	14	16	19	21	23	26	28
50	55	4627	4664	4701	4738	4776	4812	4850	4887	4925	4962	6	2	5	7	10	12	15	17	20	22	25	27	30
4 10	60	5383	5421	5460	5499	5538	5577	5616	5656	5695	5734	7	3	5	8	10	13	16	19	21	24	27	29	32
30	65	6173	6214	6254	6294	6335	6376	6416	6457	6498	6539	7	3	5	8	11	14	16	19	22	24	27	30	33
50	70	6993	7035	7076	7118	7160	7202	7244	7286	7328	7370	7	3	6	8	11	14	17	20	22	25	28	31	33
5 10	75	7836	7878	7921	7964	8006	8049	8092	8135	8178	8221	7	3	6	9	11	14	17	20	23	26	29	31	34
30	80	8695	8738	8781	8825	8868	8911	8955	8998	9042	9085	7	3	6	9	11	14	17	20	23	26	29	32	34
50	85	9564	9607	9651	9695	9738	9782	9825	9869	9913	9956	7	3	6	9	12	15	17	20	23	26	29	32	35

Table (B) LOG-SECANTS of LAT. and DEC.															PARTS.																					
Deg.	0	0	0	15	0	30	0	45	1	0	1	15	1	30	1	45	2	0	2	15	1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
0°									1		1		1		2		3		3																	
5	17		18		20		22		24		26		28		30		32		35																	
10	66		70		73		77		81		84		88		92		96		100	-1	1	1		1	1	1	1	1	1	1	1	1	2	2	2	
15	151		156		161		166		171		177		183		188		194		200	-1	1	1	1	2	2	3	3	3	4	4	4	4	4	5	5	
20	276		277		284		291		298		306		313		321		328		336	-1	1	1	1	2	2	3	3	4	4	4	5	5	6	6	7	
25	427		436		445		454		463		473		482		492		501		511	-1	1	1	2	2	3	3	4	4	4	5	6	6	7	8	8	9
30	625		636		647		658		669		681		692		704		716		728	-2	1	2	2	3	4	5	5	6	7	7	8	8	9	10	11	
35	868		880		893		907		920		934		948		962		977		991	-2	1	2	3	4	5	6	6	7	8	9	10	11	12	12	13	
40	1157		1173		1190		1206		1222		1239		1255		1272		1289		1306	-3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	16	
45	1505		1524		1543		1563		1582		1602		1622		1642		1662		1683	-4	1	3	4	5	7	8	9	11	12	13	15	16	17	18		
50	1919		1942		1965		1988		2011		2035		2058		2082		2107		2131	-5	2	3	5	6	8	9	10	11	13	14	16	17	19	21	22	
55	2414		2441		2469		2496		2524		2553		2581		2610		2639		2668	-5	2	4	6	8	9	11	13	15	17	19	21	23	25	26		

THE TIME AT SEA.

Table (C) LOG-VERS. HOUR-ANGLE.

PARTS.

H. M.	m	m	m	m	m	m	m	m	m	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
	0	1	2	3	4	5	6	7	8	9	1	4	8	12	16	20	24	28	32	36	40	44	48	52	56
1 0	5524	5467	5607	5745	5881	6015	6147	6277	6404	6530	2	9	18	27	35	44	55	62	71	80	89	97	100	115	124
10	6654	6770	6897	7016	7135	7248	7362	7475	7586	7695	2	8	13	23	31	38	46	54	61	69	77	84	92	100	107
20	7804	7910	8016	8120	8223	8325	8425	8524	8622	8719	2	7	13	20	27	34	40	47	54	61	67	74	81	87	94
30	8815	8910	9008	9096	9188	9278	9368	9457	9544	9631	2	6	12	18	24	30	36	42	48	54	60	66	72	78	84
40	9717	9802	9886	9970	0052	0134	0215	0295	0374	0453	1	5	11	16	22	27	32	38	43	49	54	59	65	70	76
50	0530	0607	0684	0759	0834	0909	0982	1055	1127	1198	1	5	10	15	20	25	30	35	39	44	49	54	59	64	69
2 0	1270	1341	1410	1480	1548	1616	1684	1751	1817	1883	1	4	9	14	18	23	27	32	36	41	45	50	54	59	63
10	1948	2018	2077	2141	2204	2267	2323	2391	2452	2513	1	4	8	12	17	21	25	29	33	37	41	46	50	54	58
20	2573	2633	2692	2751	2810	2868	2926	2983	3040	3096	1	4	8	12	15	19	23	27	31	35	39	42	46	50	54
30	3152	3208	3263	3318	3372	3426	3480	3533	3586	3639	1	4	7	11	14	18	22	25	29	32	36	40	42	47	50
40	3691	3743	3795	3846	3897	3947	3997	4047	4097	4146	1	3	7	10	13	17	20	23	27	30	33	37	40	43	47
50	4195	4245	4292	4340	4387	4435	4482	4529	4575	4621	1	3	6	9	12	16	19	22	25	28	31	34	38	41	44
3 0	4667	4713	4758	4803	4848	4892	4937	4981	5024	5068	-7	3	6	9	12	15	18	20	23	26	29	32	35	38	41
10	5111	5154	5197	5239	5281	5323	5365	5406	5447	5488	-7	3	6	8	11	14	17	20	22	25	28	31	34	36	39
20	5529	5570	5610	5650	5690	5730	5769	5808	5847	5886	-7	3	5	8	10	13	16	18	21	23	26	29	31	34	36
30	5924	5963	6001	6038	6076	6114	6151	6188	6225	6262	-6	2	5	7	10	12	15	17	20	22	25	27	30	32	34
40	6298	6335	6371	6407	6442	6475	6513	6549	6584	6618	-6	2	5	7	9	12	14	16	19	21	23	26	28	30	33
50	6653	6687	6722	6756	6790	6823	6857	6890	6924	6957	-6	2	4	7	9	11	14	16	18	20	23	25	27	29	32
4 0	6990	7022	7055	7087	7120	7152	7184	7215	7247	7278	-6	2	4	6	8	11	13	15	17	19	21	23	26	28	30
10	7310	7341	7372	7403	7433	7464	7491	7525	7555	7585	-5	2	4	6	8	10	12	14	16	17	20	22	24	26	28
20	7615	7644	7674	7703	7732	7762	7791	7819	7848	7877	-5	2	4	8	10	12	13	15	17	19	21	23	25	27	29
30	7905	7933	7961	7990	8017	8045	8073	8100	8128	8155	-5	2	4	7	9	11	13	15	17	19	20	22	24	26	28
40	8182	8209	8236	8263	8289	8316	8342	8368	8395	8421	-4	2	3	5	7	9	10	12	14	16	17	19	21	22	24
50	8447	8472	8498	8524	8549	8574	8600	8625	8650	8674	-4	2	3	5	7	8	10	12	13	15	17	18	20	22	23
5 0	8609	8724	8748	8773	8797	8821	8845	8869	8893	8917	-4	2	3	5	6	8	10	11	13	14	16	18	19	21	22
10	8941	8964	8988	9011	9034	9059	9080	9103	9126	9149	-4	1	3	5	6	8	9	11	12	14	15	17	18	20	22
20	9172	9194	9217	9239	9261	9283	9305	9327	9349	9371	-4	1	3	4	6	7	9	10	12	13	15	16	18	19	21
30	9393	9414	9436	9457	9478	9499	9520	9541	9562	9583	-4	1	3	4	6	7	8	10	11	13	14	15	17	18	20
40	9604	9625	9645	9666	9686	9706	9726	9746	9766	9786	-3	1	3	4	5	7	8	9	11	12	13	15	16	17	19
50	9806	9826	9846	9865	9885	9904	9923	9943	9962	9981	-3	1	2	4	5	6	8	9	10	11	13	14	15	16	18
6 0	0000	0019	0038	0056	0075	0094	0112	0130	0149	0167	-3	1	2	4	5	6	7	8	10	11	12	13	14	16	17
10	0185	0203	0221	0239	0257	0275	0293	0310	0328	0345	-3	1	2	3	4	6	7	8	9	10	11	12	14	15	16
20	0363	0380	0397	0415	0432	0449	0466	0482	0499	0516	-3	1	2	4	6	7	8	9	10	11	12	14	15	16	17
30	0533	0549	0566	0582	0598	0615	0631	0647	0663	0679	-3	1	2	3	4	5	6	7	8	10	11	12	13	14	15
40	0695	0711	0727	0743	0758	0774	0789	0805	0820	0836	-3	1	2	3	4	5	6	7	8	10	11	12	13	14	15
50	0851	0866	0881	0896	0911	0926	0941	0956	0970	0985	-3	1	2	3	4	5	6	7	8	10	11	12	13	14	15

Table (B) LOG-SECANTS of LAT. and DEC

PARTS.

Deg.	230	245	3	0	315	330	345	4	0	415	430	445	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0	4	5	6	7	8	9	11	12	13	15								1	1	1	1	1	1	1	1	1
5	37	40	42	45	48	51	54	57	60	63			1	1	1	1	1	1	1	2	2	2	2	2	3	3
10	104	108	113	117	122	126	131	136	141	146			1	1	1	2	2	2	3	3	3	4	4	4	4	4
15	206	212	218	224	230	237	243	250	257	263			1	1	2	3	3	3	3	4	4	4	5	5	6	6
20	344	352	360	368	376	384	393	401	410	418			1	1	2	3	3	3	4	4	5	6	6	7	7	8
25	521	531	541	551	561	571	582	592	603	614			1	1	1	2	3	3	4	5	6	6	7	8	9	10
30	740	752	764	776	789	802	814	827	840	853			2	1	2	3	4	5	6	7	8	8	9	10	11	12
35	1005	1020	1035	1050	1065	1080	1095	1110	1126	1142			2	1	2	3	4	5	6	7	8	9	10	11	12	13
40	1324	1341	1359	1376	1394	1412	1431	1449	1468	1486			3	1	2	4	5	6	7	8	10	11	12	13	14	16
45	1703	1724	1745	1766	1787	1809	1831	1852	1874	1897			4	1	3	4	6	7	9	10	12	13	14	16	17	19
50	2156	2180	2205	2231	2256	2282	2308	2334	2360	2387			5	2	3	5	7	9	10	12	14	15	17	19	21	22
55	2698	2728	2758	2788	2819	2850	2882	2913	2945	2978			5	2	4	6	8	10	12	15	17	19	21	23	25	27

Table (D). MERIDIAN ZENITH-DISTANCE.

Alt.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	Alt.
5°	9604	9603	9601	9597	9592	9586	9578	9568	9557	9545	9531	9518	5°
6	9521	9520	9518	9514	9509	9502	9494	9484	9473	9460	9446	9430	6
7	9438	9435	9433	9429	9424	9417	9408	9399	9387	9374	9360	9344	7
8	9344	9343	9341	9342	9337	9330	9321	9311	9300	9287	9272	9255	8
9	9261	9260	9258	9254	9249	9242	9233	9223	9211	9197	9182	9166	9
10	9172	9171	9168	9164	9159	9152	9143	9132	9120	9106	9091	9074	10
11	9081	9079	9077	9073	9067	9060	9051	9040	9028	9014	8998	8981	11
12	8968	8967	8964	8959	8952	8947	8938	8927	8914	8900	8884	8866	12
13	8892	8892	8890	8886	8880	8872	8862	8851	8838	8824	8807	8789	13
14	8797	8796	8794	8789	8783	8775	8766	8754	8741	8726	8709	8691	14
15	8690	8688	8686	8681	8675	8677	8667	8655	8642	8626	8609	8590	15
16	8600	8599	8596	8591	8585	8577	8567	8555	8541	8525	8507	8488	16
17	8498	8497	8494	8490	8483	8475	8464	8452	8438	8422	8404	8384	17
18	8395	8394	8391	8386	8379	8371	8360	8348	8333	8317	8298	8278	18
19	8283	8282	8280	8275	8268	8260	8254	8241	8226	8209	8190	8169	19
20	8182	8181	8178	8173	8166	8157	8146	8133	8117	8100	8081	8059	20
21	8073	8072	8069	8064	8056	8047	8036	8022	8006	7989	7969	7947	21
22	7931	7930	7927	7922	7915	7905	7893	7879	7863	7845	7825	7802	22
23	7788	7787	7784	7779	7771	7762	7750	7735	7718	7700	7680	7658	23
24	7632	7631	7628	7623	7615	7605	7592	7578	7561	7543	7523	7500	24
25	7615	7613	7610	7604	7596	7586	7573	7558	7541	7521	7499	7474	25
26	7495	7493	7490	7484	7476	7465	7452	7437	7419	7398	7375	7350	26
27	7372	7371	7367	7361	7353	7342	7328	7312	7294	7273	7249	7223	27
28	7247	7246	7243	7236	7227	7216	7202	7186	7167	7145	7121	7094	28
29	7120	7118	7115	7108	7099	7087	7073	7056	7037	7015	6990	6962	29
30	6990	6988	6984	6978	6968	6956	6942	6924	6904	6881	6856	6827	30
31	6857	6856	6852	6845	6835	6823	6808	6790	6769	6745	6719	6689	31
32	6722	6720	6716	6709	6699	6686	6671	6652	6631	6607	6579	6549	32
33	6584	6582	6578	6570	6560	6547	6531	6512	6490	6464	6436	6405	33
34	6443	6441	6436	6429	6418	6405	6388	6368	6345	6319	6290	6258	34
35	6298	6297	6292	6284	6274	6259	6242	6222	6198	6171	6141	6107	35
36	6181	6180	6175	6167	6157	6141	6121	6098	6072	6044	6012	5978	36
37	6001	5999	5994	5986	5975	5959	5941	5919	5893	5864	5832	5796	37
38	5847	5845	5840	5832	5820	5804	5785	5762	5736	5706	5672	5634	38
39	5690	5688	5683	5674	5661	5645	5625	5602	5574	5543	5508	5469	39
40	5529	5527	5522	5513	5500	5483	5462	5438	5409	5377	5341	5300	40
41	5365	5363	5357	5348	5334	5317	5295	5270	5240	5207	5169	5126	41
42	5197	5195	5189	5179	5164	5146	5124	5098	5067	5032	4992	4948	42
43	5024	5022	5016	5006	4991	4972	4949	4921	4889	4853	4812	4766	43
44	4848	4846	4839	4828	4813	4793	4769	4741	4707	4669	4626	4578	44
45	4667	4665	4658	4647	4631	4610	4585	4555	4520	4481	4436	4386	45
46	4482	4479	4472	4461	4444	4423	4396	4365	4329	4287	4240	4188	46
47	4292	4289	4282	4270	4252	4230	4202	4170	4132	4088	4039	3984	47
48	4097	4094	4087	4074	4056	4032	4003	3969	3929	3883	3832	3775	48
49	3897	3894	3886	3872	3853	3829	3799	3763	3721	3673	3619	3559	49
50	3691	3688	3680	3666	3646	3620	3588	3551	3507	3457	3400	3336	50
51	3480	3477	3468	3453	3433	3405	3372	3332	3286	3233	3174	3107	51
52	3263	3260	3251	3235	3213	3184	3149	3108	3059	3003	2940	2869	52
53	3040	3036	3027	3010	2987	2957	2920	2876	2825	2766	2699	2624	53
54	2810	2806	2796	2779	2754	2728	2683	2637	2583	2520	2450	2371	54
55	2573	2570	2559	2540	2514	2481	2440	2390	2333	2267	2192	2108	55
56	2329	2325	2313	2294	2267	2231	2188	2135	2074	2004	1925	1835	56
57	2077	2073	2061	2040	2011	1973	1927	1872	1807	1732	1648	1552	57
58	1817	1813	1800	1778	1747	1707	1658	1599	1530	1450	1360	1257	58
59	1548	1544	1530	1506	1474	1431	1378	1316	1242	1157	1060	9950	59
60	1270	1265	1250	1226	1191	1145	1089	1022	9943	9851	9747	9630	60
61	0982	0977	0961	0935	0897	0848	0788	0716	0631	0533	0421	0294	61
62	0684	0678	0661	0633	0592	0540	0476	0398	0307	0201	0080	9942	62
63	0374	0368	0350	0319	0276	0220	0150	0066	9968	9853	9722	9572	63
64	0052	0046	0026	9993	9946	9886	9810	9720	9613	9489	9346	9182	64

Table (D) MERIDIAN ZENITH-DISTANCE.

ALT.	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	ALT.
5°	9499	9480	9460	9439	9416	9391	9365	9337	9307	9276	9243	9208	5°
6	9413	9394	9374	9352	9328	9303	9276	9248	9218	9186	9152	9117	6
7	9326	9307	9286	9264	9240	9214	9187	9157	9127	9094	9060	9024	7
8	9237	9218	9197	9174	9149	9123	9095	9065	9034	9000	8965	8928	8
9	9147	9127	9106	9082	9057	9030	9002	8971	8939	8905	8869	8831	9
10	9055	9035	9013	8989	8963	8936	8906	8875	8843	8808	8771	8732	10
11	8962	8941	8918	8894	8867	8839	8810	8778	8744	8709	8671	8631	11
12	8866	8845	8822	8797	8770	8741	8711	8678	8644	8607	8569	8528	12
13	8769	8747	8724	8698	8671	8641	8610	8577	8541	8504	8465	8423	13
14	8670	8648	8624	8597	8569	8539	8507	8473	8437	8399	8359	8316	14
15	8569	8546	8522	8495	8466	8435	8403	8368	8331	8291	8250	8207	15
16	8467	8443	8418	8390	8361	8329	8296	8260	8222	8182	8139	8095	16
17	8362	8338	8312	8284	8254	8221	8187	8150	8111	8070	8028	7984	17
18	8255	8230	8204	8175	8144	8111	8076	8038	7998	7956	7911	7864	18
19	8146	8121	8094	8064	8032	7999	7962	7924	7883	7839	7793	7745	19
20	8035	8010	7981	7951	7919	7884	7846	7807	7765	7720	7673	7623	20
21	7922	7896	7867	7836	7802	7767	7728	7687	7644	7598	7550	7498	21
22	7807	7780	7750	7718	7684	7647	7608	7566	7521	7474	7424	7371	22
23	7689	7661	7631	7598	7563	7525	7484	7441	7395	7347	7295	7241	23
24	7569	7541	7509	7476	7439	7400	7359	7314	7267	7217	7164	7108	24
25	7447	7417	7385	7350	7313	7273	7230	7184	7135	7084	7029	6971	25
26	7323	7292	7259	7228	7184	7143	7099	7051	7001	6948	6891	6832	26
27	7195	7163	7129	7092	7052	7010	6964	6915	6864	6809	6750	6689	27
28	7064	7032	6997	6959	6918	6874	6827	6777	6723	6666	6606	6542	28
29	6931	6898	6862	6823	6780	6735	6686	6634	6579	6520	6458	6392	29
30	6796	6761	6724	6683	6640	6593	6542	6489	6432	6371	6306	6238	30
31	6657	6621	6583	6541	6495	6447	6395	6340	6280	6217	6150	6080	31
32	6515	6478	6438	6395	6348	6298	6244	6187	6125	6060	5991	5917	32
33	6370	6332	6291	6246	6197	6145	6090	6030	5967	5899	5827	5750	33
34	6222	6182	6139	6093	6043	5989	5931	5870	5804	5733	5658	5579	34
35	6070	6029	5985	5937	5885	5829	5769	5705	5636	5563	5485	5402	35
36	5915	5872	5826	5777	5723	5665	5602	5536	5464	5388	5307	5221	36
37	5756	5712	5664	5612	5556	5496	5431	5362	5288	5208	5124	5034	37
38	5593	5547	5498	5444	5386	5323	5256	5183	5106	5023	4935	4841	38
39	5426	5379	5327	5271	5211	5145	5075	5000	4919	4832	4740	4642	39
40	5255	5206	5152	5094	5031	4963	4889	4811	4726	4636	4539	4436	40
41	5080	5029	4973	4912	4846	4775	4698	4616	4528	4433	4332	4223	41
42	4900	4846	4788	4725	4656	4581	4501	4415	4323	4223	4117	4003	42
43	4715	4659	4598	4532	4460	4382	4298	4208	4111	4007	3895	3775	43
44	4525	4467	4403	4334	4259	4177	4089	3994	3892	3783	3665	3539	44
45	4330	4269	4203	4130	4051	3965	3873	3773	3666	3550	3426	3292	45
46	4130	4066	3996	3920	3837	3747	3650	3545	3431	3309	3177	3036	46
47	3923	3856	3783	3703	3615	3521	3418	3307	3188	3058	2919	2768	47
48	3710	3640	3563	3479	3387	3287	3179	3062	2935	2797	2649	2489	48
49	3492	3418	3336	3247	3150	3045	2930	2806	2671	2525	2367	2196	49
50	3265	3187	3102	3008	2905	2793	2672	2540	2397	2241	2072	1888	50
51	3032	2950	2859	2760	2651	2532	2403	2268	2110	1943	1762	1564	51
52	2791	2703	2607	2502	2387	2261	2123	1973	1809	1631	1436	1222	52
53	2541	2448	2347	2235	2112	1978	1830	1670	1494	1301	1091	865	53
54	2282	2184	2076	1956	1825	1682	1524	1351	1162	954	725	472	54
55	2014	1909	1794	1666	1526	1372	1203	1018	811	585	336	005	55
56	1735	1624	1500	1364	1213	1047	864	666	440	019	991	961	56
57	1445	1326	1193	1047	885	705	507	028	004	973	947	919	57
58	1143	1015	872	714	539	345	012	989	962	931	894	861	58
59	0827	0689	0536	0365	0174	996	972	946	916	882	843	801	59
60	0497	0348	0182	999	978	956	929	903	873	829	785	736	60
61	0151	999	980	960	937	912	886	850	813	776	727	681	61
62	976	961	941	919	893	864	832	796	759	704	656	614	62
63	940	920	892	867	847	819	785	736	687	621	554		63
64	896	874	854	826	797	758	712	665	617	541			64

Table (D). MERIDIAN ZENITH-DISTANCE.

ALT.	60°	61°	62°	63°	64°	65°	66°	67°	68°	69°	70°	71°	ALT.
5°	6158	5996	5824	5645	5456	5256	5046	4823	4566	4333	4063	3773	5°
6	5971	5801	5622	5431	5235	5025	4803	4567	4315	4046	3756	3445	6
7	5776	5598	5411	5213	5004	4782	4546	4295	4027	3738	3427	3090	7
8	5573	5386	5189	4981	4760	4525	4274	4006	3719	3408	3072	2704	8
9	5360	5164	4956	4736	4502	4252	3985	3698	3388	3052	2685	2282	9
10	5137	4930	4710	4477	4228	3961	3675	3366	3031	2665	2263	1816	10
11	4902	4683	4451	4203	3937	3651	3343	3009	2643	2242	1796	1296	11
12	4655	4423	4176	3911	3626	3318	2985	2620	2219	1774	1275	0706	12
13	4394	4147	3883	3599	3292	2959	2596	2195	1751	1252	0685	0027	13
14	4118	3854	3571	3265	2933	2570	2170	1726	1228	0661	0004	9224	14
15	3823	3541	3236	2904	2542	2143	1700	1203	0637	9980	9201		15
16	3509	3206	2874	2513	2115	1673	1176	0611	9955	9177			16
17	3173	2843	2482	2085	1643	1148	0583	9828	9151				17
18	2810	2450	2054	1613	1118	0554	9900	9123					18
19	2416	2020	1581	1096	6523	9870	9094						19
20	1986	1547	1054	0491	9389	9063							20
21	1512	1019	0457	9803	9031								21
22	0983	0422	9771	8997									22
23	0385	9735	8962										23
24	0697	8925											24
25	8886												25

Table (D). MERIDIAN ZENITH-DISTANCE.

ALT.	72°	73°	74°	75°	76°	77°	78°	79°	80°	81°	82°	83°	ALT.
5	3461	3122	2753	2347	1897	1392	0819	0156	9370				5°
6	3107	2738	2333	1863	1380	0807	0144	9359					6
7	2722	2317	1869	1366	0794	0132	9347						7
8	2300	1855	1350	0779	0118	9334							8
9	1835	1333	0763	0102	9312								9
10	1315	0745	0086	9303									10
11	0727	0067	9285										11
12	0048	9267											12
13	9246												13
14													14

Table (D). MULTIPLIERS FOR MINUTES OF ALTITUDE.

MIN.	0'	1'	2'	3'	4'	5'	6'	7'	8'	9'	10'
0	·00	·02	·03	·05	·07	·08	·10	·12	·13	·15	·17
10	·17	·18	·20	·22	·23	·25	·27	·28	·30	·32	·33
20	·33	·35	·37	·38	·40	·42	·43	·45	·47	·48	·50
30	·50	·52	·53	·55	·57	·58	·60	·62	·63	·65	·67
40	·67	·68	·70	·72	·74	·75	·77	·78	·80	·82	·83
50	·83	·85	·87	·88	·90	·92	·93	·95	·97	·98	1·00

Bearing.	Table (E).															LATITUDE.															
	0	4	8	10	12	14	16	18	20	22	24	26	28	30	32	0	4	8	10	12	14	16	18	20	22	24	26	28	30	32	
10	5.67	5.70	5.73	5.76	5.79	5.85	5.91	5.97	6.03	6.12	6.21	6.30	6.42	6.55	6.69																
12	4.71	4.72	4.75	4.78	4.81	4.85	4.89	4.95	5.01	5.08	5.16	5.28	5.34	5.43	5.55																
14	4.01	4.02	4.04	4.06	4.09	4.12	4.16	4.20	4.26	4.32	4.38	4.46	4.54	4.63	4.73																
16	3.49	3.50	3.52	3.54	3.56	3.59	3.62	3.66	3.70	3.76	3.82	3.88	3.94	4.02	4.11																
18	3.08	3.09	3.11	3.13	3.15	3.18	3.20	3.24	3.28	3.32	3.37	3.43	3.49	3.55	3.63																
20	2.75	2.76	2.78	2.79	2.81	2.83	2.86	2.89	2.92	2.96	3.01	3.06	3.12	3.17	3.24																
22	2.47	2.47	2.48	2.50	2.52	2.54	2.57	2.60	2.63	2.66	2.70	2.75	2.80	2.86	2.92																
24	2.25	2.26	2.27	2.28	2.30	2.32	2.34	2.37	2.39	2.43	2.46	2.50	2.55	2.59	2.65																
26	2.05	2.05	2.07	2.08	2.10	2.11	2.13	2.15	2.18	2.21	2.24	2.28	2.32	2.37	2.42																
28	1.88	1.88	1.90	1.91	1.92	1.94	1.96	1.98	2.00	2.03	2.06	2.09	2.13	2.17	2.22																
30	1.73	1.73	1.75	1.76	1.77	1.78	1.80	1.82	1.84	1.87	1.89	1.92	1.96	2.00	2.04																
32	1.60	1.60	1.62	1.63	1.64	1.65	1.66	1.68	1.70	1.73	1.75	1.78	1.81	1.85	1.89																
34	1.48	1.48	1.49	1.50	1.51	1.53	1.54	1.56	1.57	1.60	1.62	1.65	1.68	1.71	1.75																
36	1.38	1.38	1.39	1.40	1.41	1.42	1.44	1.45	1.47	1.49	1.51	1.53	1.55	1.59	1.62																
38	1.28	1.28	1.28	1.29	1.30	1.31	1.32	1.34	1.35	1.37	1.39	1.41	1.44	1.48	1.51																
40	1.19	1.19	1.20	1.21	1.22	1.23	1.24	1.25	1.27	1.28	1.30	1.32	1.35	1.38	1.41																
42	1.11	1.11	1.12	1.13	1.14	1.14	1.15	1.17	1.18	1.20	1.22	1.24	1.26	1.28	1.31																
44	1.04	1.04	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.12	1.13	1.15	1.17	1.20	1.22																
46	0.97	0.97	0.98	0.98	0.99	1.00	1.01	1.02	1.03	1.04	1.06	1.07	1.09	1.11	1.14																
48	0.90	0.90	0.91	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.99	1.00	1.02	1.04	1.06																
50	0.84	0.84	0.85	0.85	0.86	0.87	0.87	0.88	0.89	0.91	0.92	0.93	0.95	0.97	0.99																
52	0.78	0.78	0.79	0.79	0.80	0.80	0.81	0.82	0.83	0.84	0.85	0.87	0.88	0.90	0.92																
54	0.73	0.73	0.73	0.74	0.74	0.75	0.75	0.76	0.77	0.78	0.79	0.81	0.82	0.84	0.86																
56	0.67	0.67	0.68	0.68	0.69	0.69	0.70	0.71	0.71	0.72	0.73	0.75	0.77	0.78	0.79																
58	0.63	0.63	0.63	0.63	0.64	0.64	0.65	0.66	0.66	0.67	0.68	0.69	0.71	0.72	0.74																
60	0.58	0.58	0.59	0.59	0.59	0.60	0.60	0.61	0.62	0.62	0.63	0.65	0.66	0.67	0.68																
62	0.53	0.53	0.54	0.54	0.54	0.55	0.55	0.56	0.56	0.57	0.58	0.59	0.60	0.61	0.63																
64	0.49	0.49	0.50	0.50	0.50	0.51	0.51	0.52	0.52	0.53	0.54	0.55	0.56	0.56	0.57																
66	0.45	0.45	0.45	0.45	0.46	0.46	0.46	0.47	0.47	0.48	0.49	0.50	0.50	0.51	0.52																
68	0.40	0.40	0.40	0.41	0.41	0.41	0.41	0.42	0.42	0.43	0.43	0.44	0.45	0.47	0.47																
70	0.38	0.36	0.36	0.37	0.37	0.37	0.37	0.38	0.38	0.39	0.39	0.40	0.41	0.42	0.43																
72	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.35	0.35	0.36	0.36	0.37	0.37	0.38																
74	0.29	0.29	0.29	0.29	0.30	0.30	0.30	0.31	0.31	0.31	0.32	0.32	0.33	0.33	0.34																
76	0.25	0.25	0.25	0.25	0.25	0.26	0.27	0.27	0.27	0.27	0.27	0.28	0.28	0.29	0.29																
78	0.21	0.21	0.21	0.21	0.21	0.22	0.22	0.22	0.22	0.23	0.23	0.23	0.23	0.24	0.25																
80	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19	0.20	0.20	0.20	0.21																
82	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.15	0.15	0.16	0.17																
84	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.12																
86	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08																
88	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04																
89	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02																
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00																

Bearing.	Table (E).															LATITUDE.															Corr. for 1' of Alt. at the Equator.
	34	36	38	40	42	44	46	48	50	52	54	56	58	60	34	36	38	40	42	44	46	48	50	52	54	56	58	60			
10	6.84	7.01	7.20	7.40	7.63	7.88	8.18	8.48	8.82	9.21	9.65	10.14	10.70	11.33	5.76																
12	5.67	5.81	5.97	6.14	6.33	6.54	6.77	7.03	7.32	7.64	8.00	8.41	8.88	9.41	4.70																
14	4.84	4.95	5.09	5.23	5.40	5.58	5.77	5.99	6.24	6.51	6.82	7.17	7.57	8.02	4.13																
16	4.21	4.31	4.43	4.55	4.69	4.85	5.03	5.21	5.42	5.66	5.93	6.24	6.58	6.97	3.63																
18	3.71	3.80	3.90	4.02	4.14	4.28	4.43	4.60	4.79	5.00	5.24	5.50	5.81	6.15	3.24																
20	3.31	3.39	3.49	3.59	3.70	3.82	3.95	4.11	4.27	4.46	4.67	4.91	5.19	5.49	2.92																
22	2.98	3.06	3.14	3.23	3.33	3.44	3.56	3.70	3.85	4.02	4.21	4.43	4.67	4.95	2.67																
24	2.71	2.77	2.85	2.93	3.02	3.12	3.23	3.36	3.49	3.65	3.82	4.02	4.24	4.49	2.46																
26	2.47	2.53	2.60	2.68	2.76	2.85	2.95	3.06	3.19	3.33	3.49	3.68	3.87	4.10	2.28																
28	2.27	2.32	2.39	2.45	2.53	2.61	2.71	2.81	2.92	3.05	3.20	3.36	3.55	3.76	2.13																
30	2.09	2.14	2.20	2.26	2.33	2.41	2.49	2.60	2.69	2.81	2.95	3.10	3.27	3.46	2.00																
32	1.93	1.98	2.03	2.09	2.15	2.22	2.30	2.39	2.49	2.60	2.72	2.86	3.02	3.20	1.89																
34	1.79	1.83	1.88	1.93	1.99	2.06	2.13	2.22	2.31	2.41	2.52	2.65	2.80	2.96	1.79																
36	1.66	1.70	1.74	1.80	1.85	1.91	1.98	2.06	2.14	2.24	2.34	2.46	2.60	2.75	1.70																
38	1.54	1.58	1.62	1.67	1.72	1.78	1.84	1.91	1.99	2.08	2.18	2.29	2.41	2.56	1.62																
40	1.44	1.47	1.51	1.55	1.60	1.66	1.72	1.78	1.85	1.94	2.03	2.13	2.25	2.38	1.56																
42	1.34	1.37	1.41	1.45	1.49	1.54	1.60	1.66	1.73	1.80	1.89	1.99	2.09	2.22	1.49																
44	1.25	1.28	1.31	1.35	1.39	1.44	1.49	1.55	1.61	1.68	1.76	1.85	1.95	2.07	1.44																
46	1.16	1.19	1.23	1.26	1.30	1.34	1.39	1.44	1.50	1.56	1.64	1.73	1.82	1.93	1.39																
48	1.09	1.11	1.14	1.17	1.21	1.25	1.30	1.35	1.40	1.46	1.53	1.61	1.70	1.80	1.35																
50	1.01	1.04	1.06	1.09	1.13	1.16	1.21	1.25	1.31	1.36	1.43	1.50	1.58	1.68	1.31																
52	0.94	0.96	0.99	1.01	1.05	1.09	1.12	1.17	1.22	1.27	1.33	1.40	1.47	1.56	1.27																
54	0.88	0.90	0.92	0.95	0.98	1.01	1.04	1.09	1.13	1.18	1.23	1.30	1.37	1.45	1.24																
56	0.81	0.83	0.85	0.88	0.91	0.94	0.97	1.01	1.05	1.10	1.15	1.21	1.27	1.35	1.21																
58	0.75	0.77	0.79	0.81	0.84	0.87	0.90	0.93	0.97	1.01	1.06	1.12	1.18	1.25	1.18																
60	0.70	0.71	0.73	0.75	0.78	0.80	0.83	0.86	0.90	0.94	0.98	1.03	1.09	1.15	1.15																
62	0.64	0.66	0.67	0.69	0.72	0.74	0.76	0.79	0.83	0.86	0.90	0.95	1.00	1.06	1.13																
64	0.59	0.60	0.62	0.64	0.66	0.68	0.70	0.73	0.76	0.79	0.83	0.87	0.92	0.97	1.11																
66	0.54	0.55	0.56	0.58	0.60	0.62	0.64	0.66	0.69	0.72	0.76	0.79	0.84	0.89	1.09																
68	0.49	0.50	0.51	0.53	0.54	0.56	0.58	0.60	0.63	0.65	0.69	0.73	0.76	0.81	1.08																
70	0.44	0.45	0.46	0.47	0.49	0.51	0.52	0.54	0.57	0.59	0.62	0.65	0.68	0.73	1.06																
72	0.39	0.40	0.41	0.42	0.44	0.45	0.47	0.49	0.51	0.53	0.55	0.58	0.61	0.65	1.05																
74	0.34	0.36	0.36	0.37	0.38	0.40	0.41	0.43	0.44	0.46	0.49	0.52	0.54	0.57	1.04																
76	0.30	0.31	0.31	0.32	0.33	0.34	0.36	0.37	0.39	0.40	0.42	0.45	0.47	0.50	1.03																
78	0.25	0.26	0.27	0.28	0.29	0.29	0.30	0.32	0.33	0.34	0.36	0.38	0.40	0.42	1.02																
80	0.21	0.22	0.22	0.23	0.24	0.24	0.25	0.26	0.27	0.29	0.30	0.31	0.33	0.35	1.02																
82	0.17	0.17	0.18	0.18	0.19	0.19	0.20	0.21	0.22	0.23	0.24	0.25	0.26	0.27	1.01																
84	0.13	0.13	0.13	0.14	0.14	0.14	0.15	0.16	0.16	0.17	0.18	0.19	0.20	0.21	1.01																
86	0.08	0.08	0.09	0.09	0.09	0.09	0.10	0.10	0.11	0.11	0.12	0.12	0.13	0.14	1.00																
88	0.01	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.07	0.07	1.00																
89	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.04	0.05	0.05	1.00																
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00																

NOTES.

I.—If it be desired to take more than one altitude in the manner directed on page 5, set the sextant first at $30^\circ - 11'$, and secondly at $30^\circ + 11'$, when the Mean of the two will be 30° , as required. This applies to A.M. sights: For P.M. we must begin with the greatest altitude and proceed in like manner.

To take four altitudes, set the sextant at $30^\circ - 22'$, $30^\circ - 11'$, $30^\circ + 11'$ and $30^\circ + 22'$, for A.M. sights; and in the reverse order for P.M. observations.

II.—Application of Tables A, B, C, to finding the Altitude Azimuth.

(a) *Lat. and Dec. of same name*: Take difference of lat. and alt.

(b) *Lat. and Dec. of contrary names*: Take sum of lat and alt.

For North declination, take N.P.D. and reckon Azimuth from North. For South declination, take S.P.D. and reckon Azimuth from South, and proceed as in finding the time.

Example I., A.M.				Example II., P.M.			
Lat. $23^\circ 45' N.$, Alt. $21^\circ 42'$, Dec. $20^\circ 49' N.$				Lat. $25^\circ 31' N.$, Dec. $14^\circ 47' S.$, Alt. $15^\circ 46'$			
Lat. $23^\circ 45' N.$ 384				Lat. $25^\circ 31' N.$ 446			
Tab. A.	Alt. $21^\circ 42'$		319	Tab. A.	Alt. $15^\circ 46'$		166
6	Diff.	2 3		2486	Sum	41 17	
6446	N.P.D. 69 11			7449	S.P.D. 75 13		
6440	4h. 36m. 36s.		8090	4963	3h. 59m. 2s.		6958
	*5h. 3m. 48s.		8793		*4h. 18m 30s.		7570
	∴ Az. = N. $75^\circ 57'$ E.				∴ Az. = S. $64^\circ 37\frac{1}{2}'$ W.		

When the Azimuth exceeds the limit of Table (B), which it can only do when latitude and declination are of the same name, subtract the *sum* of lat. and alt. from 180° , and proceed as before, marking the Azimuth with the *contrary* name to the declination.

III.—To find the time of sunset and sunrise by the same Tables; proceed as in the following Examples:

Tab. A.	Lat.	$10^\circ 35' N.$		74
	Dec.	$23^\circ 23' S.$		372
1706	M.Z.	33 58		
10000	Z.D.	90 0		
8294	5h. 20m. 41s.			9187
Sunset	5 41	24 P.M.		9633
Sunrise	6 18	36 A.M.		

IV.—To find the Azimuth at rising or setting, make the Altitude 0° , and proceed as in Examples I and II. above,

* Thus 5h. 3m. 48s. = 303m. 48s., which divided by 4 = $75^\circ 57'$;
and 4h. 18m. 30s. = 258m. 30s., which divided by 4 = $64^\circ 37\frac{1}{2}'$.

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